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REGIONAL VARIATION IN SOLAR ENERGY ECONOMIC PERFORMANCE*

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ABSTRACT

Economic conditions underlying production functions can vary significantly in different regions. Climate, the demand for energy, and energy prices change sharply across regions; so too does the optimal mix of solar and conventional fuel inputs to the production of residential space heating. Government encouragement of solar development has been called for based on the belief that the social benefits of solar energy exceed the private benefits. Often, subsidy programs are suggested which seem to ignore underlying production function variations. In this paper the Los Alamos/UNM solar economic performance code (EASE-III) will be used to indicate the extent of these variations as applied to a Trombe wall solar design incorporated in a new home. The economic performance of the solar heated residence is compared to the alternative non-solar home heated by the characteristic conventional fuel of each region. These economic results are used to discuss the impact of subsidy programs.

1. INTRODUCTION

The solar residential space heating design analyzed here is a Trombe wall. The delivery of heat occurs by conduction, radiation and convection rather than through the use of mechanical heat transfer devices. This solar home is designed to represent a single-family detached house. Designed for Los Alamos by the Burns-Peters Architect Group, it is a 3 bedroom, 1536 square foot, single-story ranch style home. An imperative focus of the design process was to model a home that had a mass market potential. The Burns-Peters home is one that is easily adaptable to tract development and is within the financial reach of the "average" home buyer

The south wall of the home serves as the solar collector and heat storage system. The Trombe wall consists of double glazed windows in front of a poured concrete wall. The windows utilize the greenhouse effect by allowing solar radiation to pass through and heat the concrete but partially prevent the heat from escaping. The concrete wall is 12 to 18 inches thick and serves as thermal mass, storing the heat during the day and smoothing out the delivery of heat over a 24 hour period. Insulation is lowered over the outside of the wall at night to reduce heat loss. The insulation modeled has a rating of R-9. For more complete design and performance description see (1).

Economic analysis of the Trombe wall solar design begins by viewing the system as a capital good which will produce a future stream of energy savings. In theory the economic decision of the consumer involves comparing the net present value of that stream of benefits to the increased costs of the solar home when compared to a non-solar home. Other solar costs which are involved include maintenance expenses, insurance and property taxes. These costs are combined with conventional fuel costs and other economic parameters in a variant of life cycle costing to determine the competitive position of this home design across the country.

Government subsidies are designed to encourage the adoption of technologies which, on their own, might not be economically competitive with comparable conventional approaches. Different forms of subsidy are discussed with reference to their economic impact. One form of subsidy--target energy savings for new passive solar homes--is discussed in depth. The subsidy which might be required to cause consumers to adopt a passive solar heating option is defined here as the amount of money needed to allow a specifically sized design to compete economically against the conventional alternative. Three target energy savings levels are analyzed--10 MMBtu, 20 MMBtu and 30 MMBtu. The results of this analysis are used to demonstrate the impact of allowing for varying levels of inputs to the production of residential space heating on the economic efficiency of the subsidy.

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2. METHODOLOGY

The Los Alamos/UNM EASE-III code is designed to be a policy analysis tool. Due to the fact that many proposed solar policies focus on interest subsidies, tax rebates, down payment waivers or other institutional aspects of home buying, a typical consumer is modeled. This home buyer will place a 20% down payment on the total home price, increasing the total home down payment by 20% of the solar cost. Because interest payments are tax deductible a marginal income tax bracket assumption is made, 30% in this case. A mortgage period of 30 years and a system life of 30 years are chosen. It is further assumed the initial buyer will own the home for the entire system life, this avoids questions of resale valuation. What is being compared here is the total cost of heating a home for 30 years by either solar energy or through conventional fuels. The conventional home itself varies from region to region due to differing local housing standards. The Los Alamos Solar Energy Group has provided results from modified solar-load ratio correlation procedures to estimate solar performance (2). Design configuration and economic assumptions are presented in Table 1.

TABLE 1

SUMMARY OF PARAMETER VALUES

Solar Design Configuration	
Wall thickness	12-18 inches
Storage mass	1.0-1.5 ft^3/ft^2 glazing
Insulation	R-9
Economic Variables	
Fuel price escalation rates (real)	
Natural gas	4%
Electricity	2%
Heating Oil	2%
System life	30 years
Inflation rate	8%
Real interest rate	3.5%
Mortgage rate	11.5%
Income tax bracket	30%
Property tax rate	2%
Operation and Maintenance rate (% of solar cost)	1%
Down payment	20%
Design cost (regionally adjusted)	\$18/ft^2 glazing

The economic feasibility of the Trombe wall passive design is affected by many factors. Climate influences the design performance through such measures as average temperature, length of heating season, and the availability of solar radiation (3). The economic performance of the design is enhanced in locations with a long heating season, large heating requirements, and little interference with the receipt of available sunshine. Economic parameters (4) such as regional construction (5), fuel prices and interest rates greatly influence the value of the energy savings attributable to the design (6). The EASE-III data base contains information on these parameters for 220 regions in the contiguous United States.

The physical design has several parameters, all but one of which will be fixed in this analysis. Scott Noll has analyzed the impacts of changing these parameters in three varied locations: Albuquerque, New Mexico; Madison, Wisconsin; and Boston, Massachusetts (1). Two sheets of glazing, night insulation and 1.0-1.5 cubic feet of storage mass per square foot of collector are modeled here.

Holding these design parameters fixed, the design variable (with respect to the level of investment) becomes collector area. To increase the size of the solar fraction the south wall glazing area is expanded. Because the mass/area ratio is fixed, the concrete wall expands linearly with the collector area.

A constant marginal cost of collector area is assumed. However, the production of usable heat shows diminishing returns to system size when the size of the home is fixed. This creates a rising marginal cost of heat curve with a positive second derivative.

Social costs of using conventional fuels are not reflected in its price. This has resulted in the underpricing of these fuels. This leads to excessive use of conventional fuels and too little application of alternatives--passive solar for example. Raising the price of fuel to the true social cost would decrease the total energy use. Solar energy would increase and conventional fuel use would fall as indicated by the arrows in Fig. 1.

Most policy suggestions for enhanced solar application do not call for increasing energy prices. Tax breaks and subsidies are favored. If properly designed these can move toward the optimal solar investment, but still neglect the alternative conservation.

Incentive programs for solar which do not entail increasing fuel prices must be designed with an awareness of the variability of performance across regions. The current solar energy tax credit is a subsidy which can theoretically lead to an economically efficient allocation of resources to solar. If the refund percentage is equal to the percentage difference between social and private costs the individual consumer will face private decision criteria which are consistent with socially optimal benefits and costs (7). Alternative incentive programs have been suggested. Some would make the receipt of a subsidy contingent on installation of a solar system which would provide a target level of energy displacement, others require a target

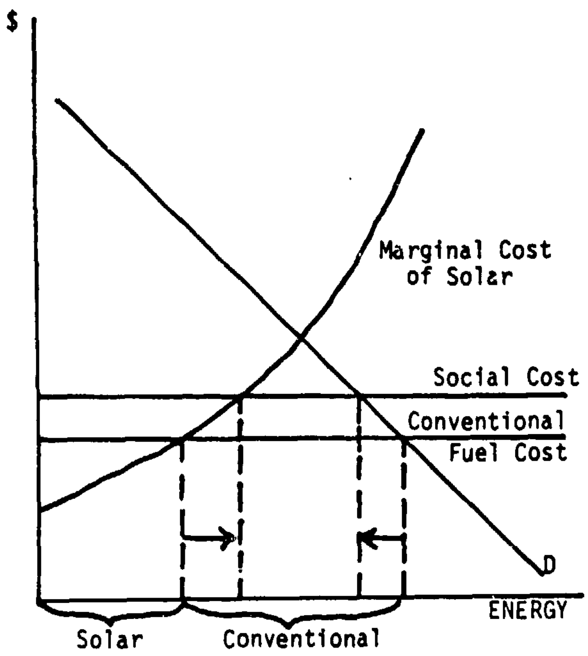


Fig. 1. Social Cost Energy Pricing

solar fraction of energy use (8). The problem with these is that they do not address the marginal conditions facing the consumer. For these incentive programs to be efficient would require that the underlying production functions be identical across regions; this is certainly not the case. The analysis undertaken for this paper uses a subsidy based on a target level of energy savings to demonstrate this point. The dollar value of subsidy required to assure economic feasibility of designs which will displace 10, 20 and 30 million Btu (MMBtu) are calculated. An alternative conventional fuel is chosen based on recent building trends (9). This fuel becomes the competing option to solar as well as the back-up fuel for the Trombe wall home. These results are discussed in the next section.

3. RESULTS

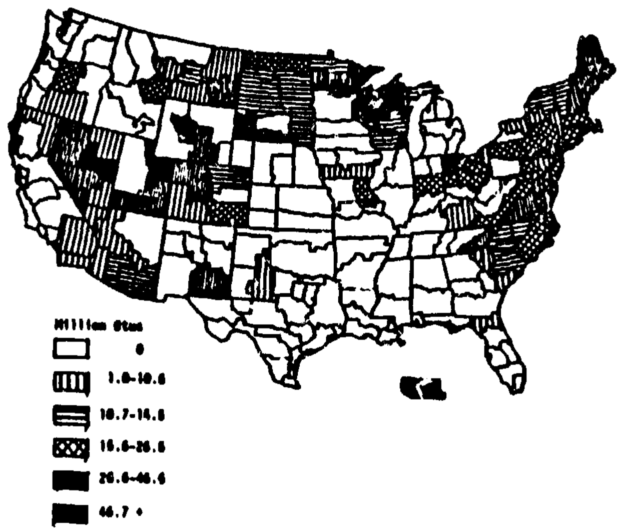
The variability in the optimal system across regions in terms of solar load savings (energy displacement) is shown in Map 1.

An ideal location for solar application would be where fuel prices are high and the weather is cold. Maine and the Western high plateaus fit that bill most closely.

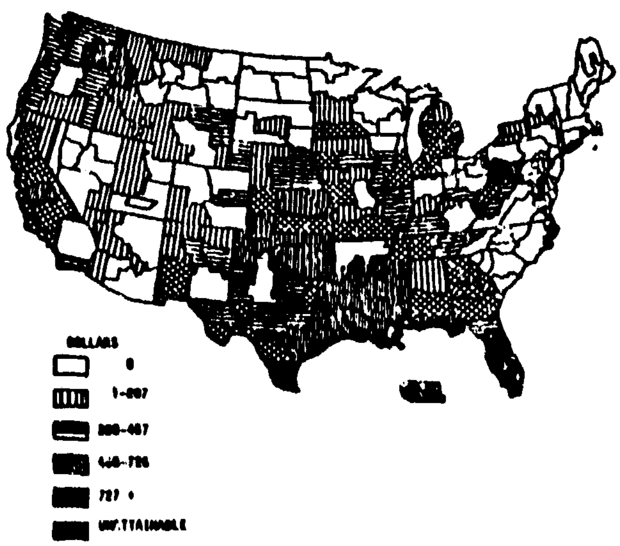
Perhaps disappointing to solar boosters is the observation that the optimal level of solar investment without subsidy in over half the regions is zero. Low priced competing conventional fuels account for this result.

Target energy savings from solar are examined next. The solar fractions needed to achieve 10, 20 and 30 million Btu's of energy displacement are shown on Maps 2, 3, and 4. In some regions the total load may be less than 30 million or the collector area required may exceed the limit of 448 square feet. In these cases no results are presented.

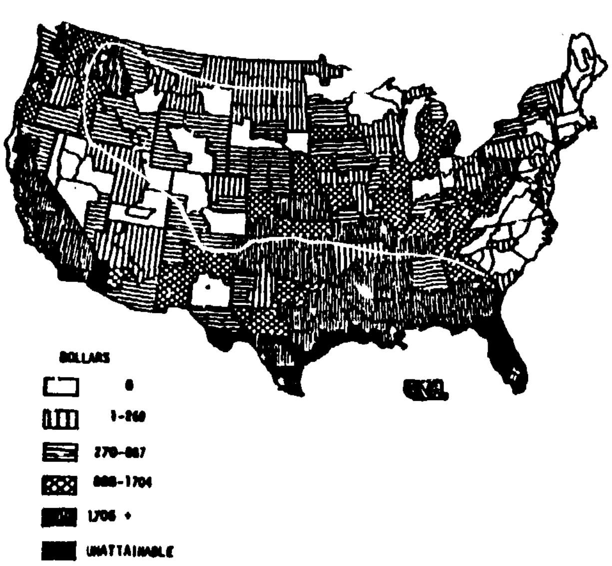
If the system size which would produce these levels of savings is greater than the consumer optimum size the target size system would entail a negative net present value. That is, costs would exceed benefits or, that an opportunity cost is incurred in not building the optimal size system. This negative value is printed as the amount of subsidy incentive required to make the consumer indifferent between the target size and his pre-subsidy optimum (often at zero).



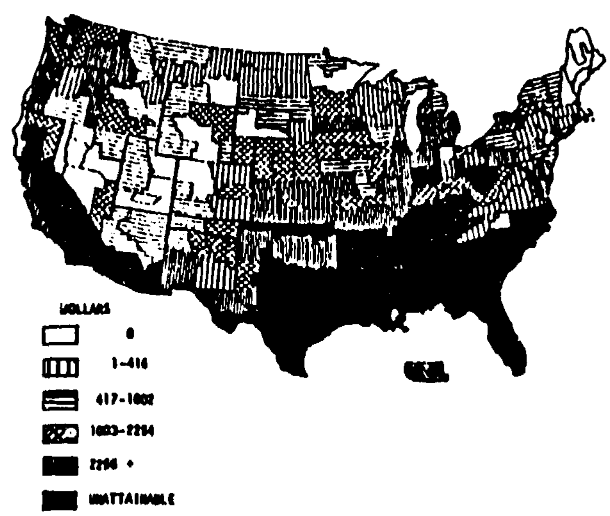
Map 1. Energy Use Displaced by Solar Pre-Subsidy Optimal System Size



Map 2. Subsidy Required for Solar Feasibility System Sized for 10 MMBtus Savings



Map 3. Subsidy Required for Solar Feasibility System Sized for 20 MMBtus Savings



Map 4. Subsidy Required for Solar Feasibility System Sized for 30 MMBtus Savings

For example, in Phoenix the optimally sized system would provide 50% of energy use displacing 14.1 million Btu's. This system has a net present value of $1121. To save 10 MMBtu's would then require no subsidy. To save 20 MMBtu's would require a 75% fraction and $913 subsidy. Thirty MMBtu's of savings is unattainable in Phoenix since the total load is only 28.3 MMBtu's per year.

As suggested above, a program that induces customers in different regions to displace identical amounts of energy leads to a misallocation of resources. The misallocation does not arise simply because the solar system has a negative net present value to the consumer. As mentioned before, the rationale for the subsidy was that solar energy produced social benefits that the individual consumer did not internalize into his investment decision. The inefficiency in this form of subsidy lies in an incorrect distribution of resources devoted to energy savings among regions.

For example, in Pocatello, Idaho the private consumer without subsidy would choose to not build a solar system. However, a subsidy of $784 could induce the consumer to shift to a system size that displaces 30 MMBtu's. In many areas an energy savings of 10 MMBtu's would require a subsidy of greater than this amount ($784). For instance, to shift from no solar use to a savings of 10 MMBtus for a home in each of Sacramento, California, and Pocatello would entail a real resource cost of $804 ($705 and $99 respectively). If these resources were applied only to a home in Pocatello more than 30 MMBtus would be displaced.

This serves to illustrate the problems that arise when marginal costs and benefits are replaced by some other decision criteria. Programs aimed at a target percentage of solar contribution have similar objectionable features. A final factor to consider are administration costs. Given dramatic regional variation in cost structures different subsidy levels would have to be calculated for each region. Some method of ascertaining the performance level of different systems applying for the subsidy would also be needed. In this light, programs which are designed to alter the marginal cost and benefit functions, bringing private valuations in line with social valuations, become more attractive.

4. CONCLUSIONS

The EASE-III code simulation shows that there are dramatic differences in interregional cost structures of solar energy. These differences arise from two principle sources; variations in climate and differing conventional fuel prices. Climatic conditions affect the actual production of usable heat while fuel prices determine the value of that heat (10).

Because these cost structures vary, social policies must be cognizant of the economic ramifications of these differences. The suggestion of subsidies contingent upon targeted energy savings levels could lead to massive misallocation of resources. Certainly the results presented show equal energy displacement across regions is not an efficient allocation.

5. NOTES AND REFERENCES

(1) Noll, S.; "A Microeconomic Analysis of Solar Heating Using Production Theory," unpublished PhD. dissertation, University of New Mexico, 1980.

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(3) U.S. Department of Commerce; "Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree Days, 1941-1970," Oceanic and Atmospheric Administration Environmental Data Service (1974).

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(5) Means, R.S.; Building Construction Cost Data 1979, R. S. Means Construction (January 1979).

(6) Roach, Fred; "Conventional Fuel Prices and Futures: Data Input for the LASL/UNM EASE-II Model," Los Alamos National Laboratory (December 1979).

(7) The consumer's equilibrium will occur at the same level of investment as the social equilibrium; however, the private marginal cost curve at this point will be more price elastic than the social marginal cost.

(8) Building Energy Performance Standards as mandated by the 1978 National Energy Act.

(9) National Association of Home Builders Research Foundation, 1978 Single Family Detached Home Construction Characteristics, Rockville, Maryland (September 1979).

(10) Ben-David, Shaul; Fred Roach; Christina Kirschner; and Scott Noll; "The LASL/UNM Performance Code: A Basic Primer," Proceedings of the Fourth National Passive Solar Energy Conference, Kansas City, Missouri (October 1979).